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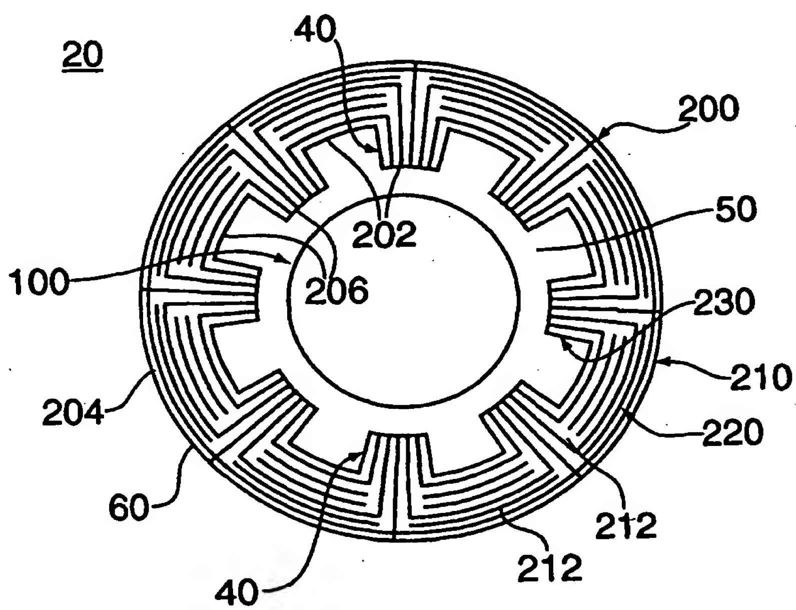

(57) Abstract

An amorphous metal stator for a high efficiency radial-flux electric motor has a plurality of segments, each f which includes a plurality of layers of amorphous metal strips. The plural segments are arranged to form a generally cylindrical stator having a plurality of teeth sections or poles protruding radially inward from the inner surface of the stator. In a first embodiment, the stator back-iron and teeth are constructed such that radial flux passing through the stator crosses just one air gap when traversing each segment f the stator. In a second embodiment, the stator back-iron and teeth are constructed such that radial flux passing through the stator traverses each segment without crossing an air gap.

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AMORPHOUS METAL STATOR FOR A RADIAL-FLUX ELECTRIC MOTOR

BACKGROUND OF THE INVENTION

1. Field Of The Invention

This invention relates to a stator for an electric motor; and more particularly, to an amorphous metal stator for a high efficiency radial-flux electric motor.

2. Description Of The Prior Art

A radial-flux design electric motor typically contains a generally cylindrical stator made from a plurality of stacked laminations of non-oriented electrical steel. Each lamination has the shape of a circular washer having "teeth" that form the poles of the stator. The teeth protrude from the inner diameter of the stacked laminations and point toward the center of the cylindrical stator. Each lamination is typically formed by stamping, punching or cutting the mechanically soft, non-oriented electrical steel into the desired shape. The formed laminations are then stacked and bound to form a stator.

Although amorphous metals offer superior magnetic performance when compared to non-oriented electrical steels, they have long been considered unsuitable for use in electric motors due to certain physical properties and the corresponding fabricating limitations. For example, amorphous metals are thinner and harder than their non-oriented steel counterparts and consequently cause fabrication tools and dies to wear more rapidly. The resulting increase in the tooling and manufacturing costs makes fabricating amorphous metal stators using such techniques commercially impractical. The thinness of amorphous

metals also translates into an increased number of laminations in the assembled stator, further increasing the total cost of an amorphous metal stator.

Amorphous metal is typically supplied in a thin continuous ribbon having a uniform ribbon width. However, amorphous metal is a very hard material and once annealed to achieve peak magnetic properties becomes very brittle. This makes it difficult and expensive to use conventional approaches to construct an amorphous metal magnetic stator. The brittleness of amorphous metal also causes concern for the durability of a motor or generator which utilizes amorphous metal magnetic stators. Magnetic stators are subject to extremely high magnetic forces which change at very high frequencies. These magnetic forces are capable of placing considerable stresses on the stator material which may damage an amorphous metal magnetic stator.

Another problem with amorphous metal magnetic stators is that the magnetic permeability of amorphous metal material is reduced when it is subjected to physical stresses. This reduced permeability may be considerable depending upon the intensity of the stresses on the amorphous metal material. As an amorphous metal magnetic stator is subjected to stresses, the efficiency at which the core directs or focuses magnetic flux is reduced, resulting in higher magnetic losses, reduced efficiency, increased heat production, and reduced power. This stress sensitivity, due to the magnetostrictive nature of the amorphous metal, may be caused by stresses resulting from magnetic forces during the operation of the motor or generator, mechanical stresses resulting from mechanical clamping or otherwise fixing the magnetic stator in place, or internal stresses caused by the thermal expansion and/or expansion due to magnetic saturation of the amorphous metal material.

Non-conventional approaches to amorphous metal stator designs have been proposed. In one approach, a "toothless" stator, consisting simply of a tape-wound amorphous metal toroid, has been suggested. While this approach produces an efficient motor, the large air gap between the stator and the rotor limits the performance and control of the motor. A second approach attempts to replicate the conventional stator shape by combining a tape-wound amorphous metal toroid with stacks of cut amorphous metal. The wound amorphous metal toroid forms the back-iron of the stator and the cut amorphous metal stacks are mounted on the inner diameter of the toroid to form the teeth or poles. While this approach reduces the air gap between the stator and rotor, the magnetic flux must cross the many layers of tape wound back-iron as the flux passes from the tooth to the back-iron. This greatly increases the electric current required to operate the motor.

SUMMARY OF THE INVENTION

The present invention provides an amorphous metal stator for a high efficiency radial-flux electric motor. Generally stated, the stator comprises a plurality of segments, each of which comprises a plurality of layers of amorphous metal strips. The plural segments are configured to form a generally cylindrical stator having a plurality of teeth sections or poles protruding radially inward from the inner surface of the stator. In a first embodiment, the stator back-iron and teeth are constructed such that radial flux passing through the stator crosses just one air gap when traversing each segment of the stator. In a second embodiment, the stator back-iron and teeth are constructed such that radial flux passing through the stator traverses each segment without crossing an air gap.

The present invention further provides a brushless radial-flux DC motor having an amorphous metal stator generally comprising a

plurality of segments, each of which comprises a plurality of layers of amorphous metal strips. The plural segments are configured to form a generally cylindrical stator having a plurality of teeth sections protruding radially inward. In a first embodiment, the stator back-iron and teeth are constructed such that radial flux passing through the stator crosses just one air gap when traversing each segment of the stator. In a second embodiment, the stator back-iron and teeth are constructed such that radial flux passing through the stator traverses each segment without crossing an air gap. The DC motor of the present invention further comprises a rotor rotatingly disposed within the stator and means for supporting the stator and rotor in predetermined positions with respect to each other.

The present invention further provides a method of constructing an amorphous metal stator for a radial flux electric motor comprising the steps of (i) forming a plurality of segments, each segment comprising a plurality of layers of amorphous metal strips; and (ii) assembling the segments together to form a stator. The segments formed in accordance with the present invention are arranged such that magnetic flux traversing each segment crosses a maximum of one air gap.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood and further advantages will become apparent when reference is had to the following detailed description of the preferred embodiments of the invention and the accompanying drawings, wherein like reference numerals denote similar elements throughout the several views and in which:

Fig. 1 is a top view of a prior art radial flux electric motor having a tape-wound amorphous metal stator and a rotor;

Figs. 2A and **2B** are top views of a prior art radial flux electric motor having a tape-wound amorphous metal stator with poles formed from stacks of cut amorphous metal;

Fig. 3 is a top view of a first embodiment of a radial flux electric motor having an amorphous metal stator constructed of a plurality of segments configured in accordance with the present invention;

Fig. 4 is a detailed view of a segment of the stator of Fig. 3;

Fig. 5 is a top view of a second embodiment of a radial flux electric motor having an amorphous metal stator constructed of a plurality of segments and configured in accordance with the present invention;

Fig. 6 is a detailed view of a segment of the stator of Fig. 5; and

Figs. 7A - 7D depict methods of constructing an amorphous metal stator in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides an amorphous metal stator for a high efficiency radial-flux electric motor. The stator of the present invention generally comprises a plurality of segments, each of which comprises a plurality of layers of amorphous metal strips. The plural segments are configured to form a generally cylindrical stator having a plurality of teeth sections or poles protruding radially inward. In a first embodiment, the stator back-iron and teeth are constructed such that radial flux passing through the stator crosses just one air gap when traversing each stator segment. In a second embodiment, the stator back-

iron and teeth are constructed such that radial flux passing through the stator traverses each segment without crossing an air gap.

Referring to the drawings, there is shown in **Fig. 1** a prior art radial flux motor 20 having a tape wound amorphous metal stator 200. The stator 200 is comprised of wound amorphous metal tape 30. A rotor 100 is disposed for rotation within the stator 200. The "toothless" configuration of the stator 200 defines a substantial air gap 50 between the stator 200 and rotor 100, which disadvantageously limits the performance and control of the motor 20.

Figs. 2A and 2B each depict a prior art radial flux motor 20 having an amorphous metal stator 200 comprised of wound amorphous metal tape 30 and having a rotor 100 disposed for rotation within the stator 200. The stator 200 includes teeth 40 or poles that extend radially inward toward the rotor 100. Each of the teeth 40 is comprised of a plurality of amorphous metal strips 42 that are oriented either generally parallel to (see, e.g. **Fig. 2A**) or generally perpendicular to (see, e.g. **Fig. 2B**) the winding direction of the wound metal tape 30. Although the air gap 50 defined between the rotor 100 and stator poles 40 is reduced when compared with the motor 20 of **Fig. 1**, the magnetic flux of the motor 20 must cross many layers of amorphous metal, i.e. traverse many air gaps, as the flux passes through the tooth 40 (for the prior art stator depicted by **Fig. 2A**) and as the flux passes through from the tooth 40 to the back-iron 60 of the stator 200. Consequently, the operational current requirements and power consumption of a motor 20 configured as depicted in **Figs. 2A and 2B** is significantly increased. In addition, the thermal characteristics of such a motor is also adversely impacted.

Referring next to **Figs. 3 and 4**, there is shown a brushless radial flux DC motor 20 constructed in accordance with the present invention. Motor 20 has a rotor 100 rotatingly disposed within a first

embodiment of an amorphous metal stator 200. The rotor 100 is rotatingly supported within the stator 200 by means known in the art. The stator 200 is made up of a predetermined number of segments 210 arranged in abutting relation with each other in a generally cylindrical form. Each segment 210 includes a back-iron section 220 and a tooth section 230 collectively comprising a plurality of layers of amorphous metal strips 212 that are individually cut to their respective predetermined sizes. Each strip 212 of the back-iron section 220 is cut to a different predetermined size and stacked so that the longest strip is located along the outer diameter of the segment 210 and the shortest strip is located along the inner diameter of the segment 210. The cut strips 212 are stackingly arranged so that metal-to-metal contact is provided among the stacked amorphous metal strips 212. The stacked strips 212 are then subjected to a forming force that imparts a bow or arcuate bend to the stacked strips 212 as depicted in **Fig. 4** (the various methods for forming the stacked strips are discussed hereinafter in further detail).

As depicted by **Fig. 4** of the drawings, strips 212 of the tooth section 230 are cut to a plurality of predetermined sizes and contactingly stacked to ensure metal-to-metal contact among the stacked strips so that the longest strip is located approximately at the center of the tooth section 230 and the strips 212 become shorter towards the outer edges of the group 230. This configuration defines two diametrically opposed first free ends 232 that collectively form a substantially V-shaped end of the tooth section 230. The stacked strips configured as described and as depicted by **Fig. 4** also define a second free end 234 of the tooth section 230 that is substantially planar and that comprises the tooth or pole 40 of the stator 200.

The back-iron section 220 and tooth section 230 include respective first free ends 222, 232 that contactingly engage each other

when the sections 220, 230 are arranged as depicted by **Fig. 4** to form a segment 210. An air gap 52 is defined between the free ends 222, 232 of the sections 220, 230 due to the fact that the sections 220, 230 comprise separate pieces of amorphous metal.

Once arranged as depicted by **Fig.** 4, the segment 210 is annealed at a temperature of about 360°C while being subjected to a magnetic field. As is well known by those skilled in the art, the annealing step operates to relieve stress in the amorphous metal material, including stresses imparted during the casting, winding, cutting, lamination arranging, forming and shaping steps. The segment 210 retains its formed shape after the annealing process.

Once a predetermined number of segments 210 are arranged to form the stator 200, as depicted in **Fig.** 3, the stator is coated or impregnated with an epoxy resin 202 to hold the segments 210 together, and also to provide mechanical strength and support to the stator 200 during use in the electric motor 20. The epoxy resin 202 is particularly effective in securing the tooth section 230, which also partly comprises the teeth or poles 40 of the stator 200, from being magnetically drawn toward the rotor 100. The epoxy resin 202 preferably covers the second free end 234 of the tooth section 230 and is not present between the first free ends 222, 232 of the first and tooth sections 220, 230. Alternatively, or in addition to the epoxy resin 202, an inner restraining band 206 may be used to secure the tooth section 230 in place and to supply the desired additional structural rigidity to the stator 200. The band 206 may secure the teeth or poles 40, the sections between the poles, or both, provided that the restraining band 206 does not significantly increase the space required between the rotor 100 and the stator teeth 40, i.e. does not significantly increase the air gap 50. An outer restraining band 204, preferably made of steel, is provided peripherally about the stator 200 to

secure the plurality of segments 210 in generally circular abutting contact with each other. The outer band 204 strengthens the overall construction of the stator 200 and provides an additional level of safety in the case of catastrophic and destructive motor failure by preventing loose motor parts from breaking loose and causing injury to persons located nearby.

The stator 200 depicted by **Fig. 3** advantageously provides a flux path therethrough which includes a single, small air gap 52 that is crossed as the flux traverses each segment 210. Consequently, the performance and control characteristics of a stator 200 constructed in accordance with the present invention are significantly improved when compared with conventional amorphous metal stators for radial flux electric motors.

Referring to **Figs. 5 and 6**, there is shown a second embodiment of the stator 200 of the present invention. Stator 200 is made up of a predetermined number of segments 250 that are generally C-shaped (when viewed in cross-section, as in **Fig. 6**) and that are arranged in abutting relation with each other in a generally cylindrical form. Each C-segment 250 is comprised of a plurality of layers of amorphous metal strips 212 that are individually cut to their respective predetermined sizes and thereafter formed to the desired shape. The strips 212 are stackingly arranged so that metal-to-metal contact is provided among the stacked amorphous metal strips 212. Two substantially planar free ends 252 are defined by each C-segment 250 that comprise, at least in part, the poles 40 of the stator 200. After being formed, the C-segments 250 are individually annealed at temperatures of about 360°C while being subjected to a magnetic field. The C-segments 250 retain their formed shape after the annealing process. Once a predetermined number of C-segments 250 are arranged to form the stator 200, as depicted in **Fig. 5**, the stator 200 is coated or impregnated with an epoxy resin 202 to hold

the C-segments 250 together, and also to provide mechanical strength and support to the stator 200 during use in the electric motor 20. The epoxy resin 202 preferably covers the two free ends 252 of the C-segment 250. Alternatively, or in addition to the epoxy resin 202, an inner restraining band 206 may be used to secure the C-segments 250 in place and to supply the desired additional structural rigidity to the stator 200. The band 206 may secure the teeth or poles 40, the sections between the poles, or both, provided that the inner restraining band 206 does not significantly increase the space required between the rotor 100 and the stator teeth 40, i.e. does not significantly increase the air gap 50. An outer restraining band 204, preferably made of steel, is provided peripherally about the stator 200 to secure the plurality of C-segments 250 in generally circular abutting relation with each other. The outer band 204 strengthens the overall construction of the stator 200 and provides an additional level of safety in the case of catastrophic and destructive motor failure by preventing loose motor parts from breaking loose and causing injury to persons located nearby.

The C-segments 250 formed in accordance with the present invention are annealed at a temperature of about 360°C while being subjected to a magnetic field. As is well known to those skilled in the art, the annealing step operates to relieve stress in the amorphous metal material, including stresses imparted during the casting, winding, cutting, lamination arranging, forming and shaping steps. The C-segment 250 retains its formed shape after the annealing process.

The inventive stator 200 depicted in **Fig. 5** advantageously permits flux to traverse each C-segment 250 without having to cross an air gap. Consequently, the performance and control characteristics of a stator 200 constructed in accordance with the present invention are

significantly improved when compared with conventional amorphous metal stators for radial flux electric motors.

Referring **Fig. 7A** of the drawings, there is shown a method for forming a generally arcuate back-iron section 220 of an amorphous metal stator segment 210 in accordance a first embodiment of the present invention. The back-iron section 220 is constructed from a plurality of amorphous metal strips 212 that are cut to a plurality of predetermined lengths from spools (not shown) of amorphous metal, as depicted in **Fig. 7A**. The cut strips 212 are stacked and bound together (ensuring that metal-to-metal contact is present among the strips 212) to form the back-iron section 220. The back-iron section 220 is then formed to the desired shape by imparting a forming force in the direction generally indicated by the arrows using a die 350 and a forming means 310. The formed back-iron section 220 and substantially straight tooth section 230 are then arranged as depicted in **Fig. 4** and annealed.

Referring to **Figs. 7B and 7C**, two methods of forming a C-segment 250 of an amorphous metal stator in accordance with a second embodiment of the present invention are there depicted. Strips of amorphous metal ribbon are measured from spools (not shown) of amorphous metal and cut to predetermined lengths. The cut strips 212 are then stacked, ensuring metal-to-metal contact among the strips, and then secured to a generally rectangular mandrel 300. For the C-segment 250, the strips 212 may be formed into the desired shape using a "punch and die" concept. More specifically, the strips 212 are strapped around the generally rectangular mandrel 300 with the mandrel 300 being the punch and the corresponding die 340 having a generally C-shaped cross-section. The mandrel 300 and attached stacked strips 212 are then directed into the die to impart the desired C-shape to the strips 212 and form the C-segment 250. Alternately, and as depicted in **Fig. 7C**, the

stacked strips 212 may first be placed on the generally C-shaped die 340, and the generally rectangular mandrel 300 thereafter directed onto the stacked strips 212 to impart the desired cross-sectional shape and form the C-segment 250.

The forming method depicted in **Figs. 7B and 7C** may also be used with spools of amorphous metal that comprise multiple layers of pre-stacked metal ribbon. This pre-stacked ribbon is cut and formed as described above.

Yet another method of forming a C-segment 250 comprises winding amorphous metal ribbon about a generally rectangular mandrel 300 to form a generally rectangular core 360 having a large aspect ratio, i.e. the ratio of the length of the long side of the rectangle to the length of the short side, as depicted in **Fig. 7D**. The aspect ratio is preferably about 3-to-1. The short sides of the rectangular core are cut approximately at the longitudinal mid-point 362 to provide two C-segments 250, i.e. one from each half of the generally rectangular core. The C-segments 250 may thereafter be annealed and sealed with an epoxy resin as described above.

The segments 210, 250 can be annealed with conventional heat treatment equipment such as batch or continuous furnace. Application of the magnetic field utilized in the anneal can be accomplished through use of circular current coils, which provide a longitudinal magnetic field when the segments are positioned therewithin. When the profile of the segments is flat (e.g. as with the tooth section 230), direct contact heating plates can also be used, practically and economically, for annealing. Also, the non-annulus, flat shape of the tooth section 230 will facilitate improved annealing cycle with faster heat up and cool down time as compared to the conventional techniques. Furthermore, the annealing cycle time and temperature can be tailored to individual segments of

varying shape, size and properties to achieve an optimum level of material ductility and magnetic performance. In affect, the resulting loss of the segments produced in accordance with the present invention will be lower than the conventional wound amorphous metal stators from lower induced stress during the segment forming process and also the improved stress relieving affect of annealing. The reduction in annealing cycle time will reduce the brittleness of the annealed amorphous metal stator segment laminations.

After annealing, the free ends 234, 252 and inner and outer peripheral edges of the segment 210 and C-segment 250 are finished with an epoxy resin coating. The epoxy resin coating 202 is completed on both interior and exterior edges to provide mechanical strength and surface protection for the transformer coil during the stator assembly process and during use as a component part of a radial flux electric motor.

The amorphous metal stator 200 of the present invention can be manufactured using numerous amorphous metal alloys. Generally stated, the alloys suitable for use in the segment 210 construction of the present invention are defined by the formula: M_{70-85} Y_{5-20} Z_{0-20}, subscripts in atom percent, where "M" is at least one of Fe, Ni and Co, "Y" is at least one of B, C and P, and "Z" is at least one of Si, Al and Ge; with the proviso that (i) up to 10 atom percent of component "M" can be replaced with at least one of the metallic species Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ta and W, and (ii) up to 10 atom percent of components (Y + Z) can be replaced by at least one of the non-metallic species In, Sn, Sb and Pb. Highest induction values at low cost are achieved for alloys wherein "M" is iron, "Y" is boron and "Z" is silicon. For this reason, amorphous metal strip composed of iron-boron-silicon alloys is preferred.

Having thus described the invention in rather full detail, it will be understood that such detail need not be strictly adhered to but that further changes and modifications may suggest themselves to one skilled in the art, all falling within the scope of the invention as defined by the subjoined claims.

CLAIMS

What is claimed is:

1. An amorphous metal stator for a radial flux motor comprising a plurality of segments, each segment comprising a plurality of layers of amorphous metal strips oriented such that, when traversing said segment, said flux crosses one air gap.

2. An amorphous metal stator as recited by claim 1, each of said segments further comprising:
   a. a back-iron section having a first free end and comprising a plurality of contactingly stacked layers of amorphous metal strips; and
   b. a tooth section having a first free end and comprising a plurality of contactingly stacked layers of amorphous metal strips;
   c. said back-iron section and said tooth section being arranged such that said first free end of said back-iron section contactingly engages said first free end of said tooth section and wherein an air gap is defined between said respective first free ends.

3. An amorphous metal stator as recited by claim 2, further comprising:
   a. an inner restraining means for securing said tooth section against being drawn out of engagement with said back-iron section; and

b. an outer restraining means for securing said plurality of segments in generally circular abutting relation to each other.

4. An amorphous metal stator as recited by claim 3, wherein said inner restraining means comprises a bonding material that is applied to a substantial portion of said stator to provide each of said segments with increased mechanical strength, and said outer restraining means comprises a steel band provided peripherally about said stator.

5. An amorphous metal stator as recited by claim 3, wherein said inner restraining means comprises a bonding material that is applied to a substantial portion of said stator, excluding said respective first free ends of said back-iron and tooth sections.

6. An amorphous metal stator as recited by claim 4, wherein said boding material is an epoxy resin.

7. An amorphous metal stator as recited by claim 3, wherein said inner restraining means partly comprises a bonding material and partly comprises a metal band.

8. An amorphous metal stator as recited by claim 2, said back-iron section being generally arcuate and said tooth section being generally straight.

9. An amorphous metal stator as recited by claim 1, each of said strips having a composition defined essentially by the formula: $M_{70\text{-}85}$ $Y_{5\text{-}20}$ $Z_{0\text{-}20}$, subscripts in atom percent, where "M" is at least one of Fe, Ni and Co, "Y" is at least one of B, C and P, and "Z" is at least one of Si, Al and Ge; with the provisos that (i) up to 10 atom percent of component "M" can be replaced with at least one of the metallic species Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ta and W, and (ii) up to 10 atom percent of components (Y + Z) can be replaced by at least one of the non-metallic species In, Sn, Sb and Pb.

10. An amorphous metal stator as recited by claim 1, each of said segments having been annealed with a magnetic field in a batch or continuous annealing oven.

11. An amorphous metal stator for a radial flux motor comprising a plurality of segments, each segment comprising a plurality of layers of amorphous metal strips oriented such that said flux traverses said segment without crossing an air gap.

12. An amorphous metal stator as recited by claim 11, each of said segments further comprising a plurality of contactingly stacked layers of amorphous metal strips, each of said segments having a tooth section and a back-iron section and having a generally C-shaped cross-section.

13. An amorphous metal stator as recited by claim 11, further comprising:
   a. an inner restraining means for protecting and strengthening at least said tooth section; and
   b. an outer restraining means for securing said plurality of segments in generally circular abutting relation to each other.

14. An amorphous metal stator as recited by claim 13, wherein said inner restraining means comprises a bonding material that is applied to a substantial portion of said stator and that provides each of said segments with increased mechanical strength and wherein said outer restraining means comprises a steel band provided peripherally about said stator.

15. An amorphous metal stator as recited by claim 14, wherein said boding material is an epoxy resin.

16. An amorphous metal stator as recited by claim 13, wherein said inner restraining means partly comprises a bonding material and partly comprises a metal band.

17. An amorphous metal stator as recited by claim 11, each of said strips having a composition defined essentially by the formula: $M_{70-85}\ Y_{5-20}\ Z_{0-20}$, subscripts in atom percent, where "M" is at least one of Fe, Ni and Co, "Y" is at least one of B, C and P, and "Z" is at least one of Si, Al and Ge; with the provisos that (i) up to 10 atom

percent of component "M" can be replaced with at least one of the metallic species Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ta and W, and (ii) up to 10 atom percent of components (Y + Z) can be replaced by at least one of the non-metallic species In, Sn, Sb and Pb.

18. An amorphous metal stator as recited by claim 11, each of said segments having been annealed with a magnetic field in a batch or continuous annealing oven.

19. A brushless radial flux DC motor comprising:

a. an amorphous metal stator comprising a plurality of segments, each segment comprising a plurality of layers of amorphous metal strips oriented such that, when traversing said segment, said flux crosses one air gap;
b. a rotor disposed for rotation within said stator; and
c. means for supporting said stator and said rotor in predetermined positions relative to each other.

20. A brushless radial flux DC motor comprising:

a. an amorphous metal stator comprising a plurality of segments, each segment comprising a plurality of layers of amorphous metal strips oriented such that said flux traverses said segment without crossing an air gap;
b. a rotor disposed for rotation within said stator; and

c. means for supporting said stator and said rotor in predetermined positions relative to each other.

21. A method of constructing an amorphous metal stator for a radial flux motor comprising the steps of:

(a) forming a plurality of segments, each segment comprising a plurality of layers of amorphous metal strips; and

(b) assembling said segments together to form a stator.

22. A method as recited by claim 21, wherein for each of said plurality of segments said step (a) further comprises:

(c) cutting amorphous metal strip material to a plurality of predetermined lengths;

(d) stacking said cut strip material to form a back-iron section having a first free end and a tooth section having a first free end;

(e) shaping said back-iron section to a predetermined shape;

(f) arranging said back-iron section and said tooth section to form said segment such that said respective first free ends contactingly engage each other, said back-iron section and said tooth section being oriented such that, when traversing said segment, said flux crosses one air gap; and

(g) annealing said segment.

23. A method as recited by claim 22, further comprising the steps of:

(h) applying an inner restraining means for protecting and strengthening at least said tooth section; and

(i) applying an outer restraining means for securing said plurality of segments in generally circular abutting relation to each other.

24. A method as recited by claim 23, wherein said inner restraining means comprises a bonding material that is applied to a substantial portion of said stator to provide each of said segments with increased mechanical strength, and said outer restraining means comprises a steel band provided peripherally about said stator.

25. A method as recited by claim 22, said predetermined shape of said back-iron section being generally arcuate.

26. A method as recited by claim 21, wherein for each of said plurality of segments, said step (a) further comprises the steps of:

(c) cutting amorphous metal strip material to a plurality of predetermined lengths;

(d) stacking said cut strip material;

(e) shaping said stacked strip material into a predetermined shape to form said segment having a tooth section and a back-iron section, said

stacked strip material being oriented in said segment such that said flux traverses said segment without crossing an air gap; and

(f) annealing said segment.

27. A method as recited by claim 26, further comprising the steps of:

(g) applying an inner restraining means for protecting and strengthening at least said tooth section; and

(h) applying an outer restraining means for securing said plurality of segments in generally circular abutting relation to each other.

28. A method as recited by claim 27, wherein said inner restraining means comprises a bonding material that is applied to a substantial portion of said stator and that provides each of said segments with increased mechanical strength and wherein said outer restraining means comprises a steel band provided peripherally about said stator.

29. A method as recited by claim 26, said predetermined shape of said segment being substantially C-shaped.

30. A method as recited by claim 22, said step (e) further comprising the steps of:

(h) strapping said stacked strip material to a generally rectangular mandrel; and

(i) forcing said mandrel and said strapped strip material into engagement with a die having a predetermined cross-sectional shape so as to form said strip material into the predetermined cross-sectional shape.

31. A method as recited by claim 22, said step (e) further comprising the steps of:

(h) placing said stacked strip material on a die having a predetermined cross-sectional shape; and

(i) forcing a mandrel into engagement with said stacked strip material so as to form said strip material into the predetermined cross-sectional shape.

32. A method as recited by claim 21, wherein each of said strips has a composition defined essentially by the formula: $M_{70-85}\ Y_{5-20}\ Z_{0-20}$, subscripts in atom percent, where "M" is at least one of Fe, Ni and Co, "Y" is at least one of B, C and P, and "Z" is at least one of Si, Al and Ge; with the provisos that (i) up to 10 atom percent of component "M" can be replaced with at least one of the metallic species Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ta and W, and (ii) up to 10 atom percent of components (Y + Z) can be replaced by at least one of the non-metallic species In, Sn, Sb and Pb.

33. The method as recited by claim 21, wherein for each of said plurality of segments said step (a) further comprises:

(c) winding an amorphous metal ribbon about a generally rectangular mandrel to form a generally rectangular core having two substantially parallel long sides and two substantially parallel short sides;

(d) cutting the two substantially parallel short sides approximately at their respective longitudinal mid-points to provide two C-shaped segments, each segment having a tooth section and a back-iron section and comprising a plurality of layers of amorphous metal strips oriented such that said flux traverses said segment without crossing an air gap; and

(e) annealing each of said segments.

34. A method as recited by claim 33, further comprising the steps of:

(f) applying an inner restraining means for protecting and strengthening at least said tooth section; and

(g) applying an outer restraining means for securing said plurality of segments in generally circular abutting relation to each other.

35. A method as recited by claim 34, wherein said inner restraining means comprises a bonding material that is

applied to a substantial portion of said stator to provide each of said segments with increased mechanical strength, and said outer restraining means comprises a steel band provided peripherally about said stator.

36. A method as recited by claim 33, wherein each of said strips has a composition defined essentially by the formula: $M_{70-85}\ Y_{5-20}\ Z_{0-20}$, subscripts in atom percent, where "M" is at least one of Fe, Ni and Co, "Y" is at least one of B, C and P, and "Z" is at least one of Si, Al and Ge; with the provisos that (i) up to 10 atom percent of component "M" can be replaced with at least one of the metallic species Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ta and W, and (ii) up to 10 atom percent of components (Y + Z) can be replaced by at least one of the non-metallic species In, Sn, Sb and Pb.

37. An amorphous metal stator for a radial flux motor constructed in accordance with the method recited by claim 21.

38. An amorphous metal stator for a radial flux motor constructed in accordance with the method recited by claim 22.

39. An amorphous metal stator for a radial flux motor constructed in accordance with the method recited by claim 26.

40. An amorphous metal stator for a radial flux motor constructed in accordance with the method recited by claim 33.

41. An amorphous metal stator as recited by claim 9, 17 or 32, each of said strips having a composition defined essentially by the formula: $Fe_{70-85} B_{5-20} Si_{0-20}$, subscripts in atom percent.

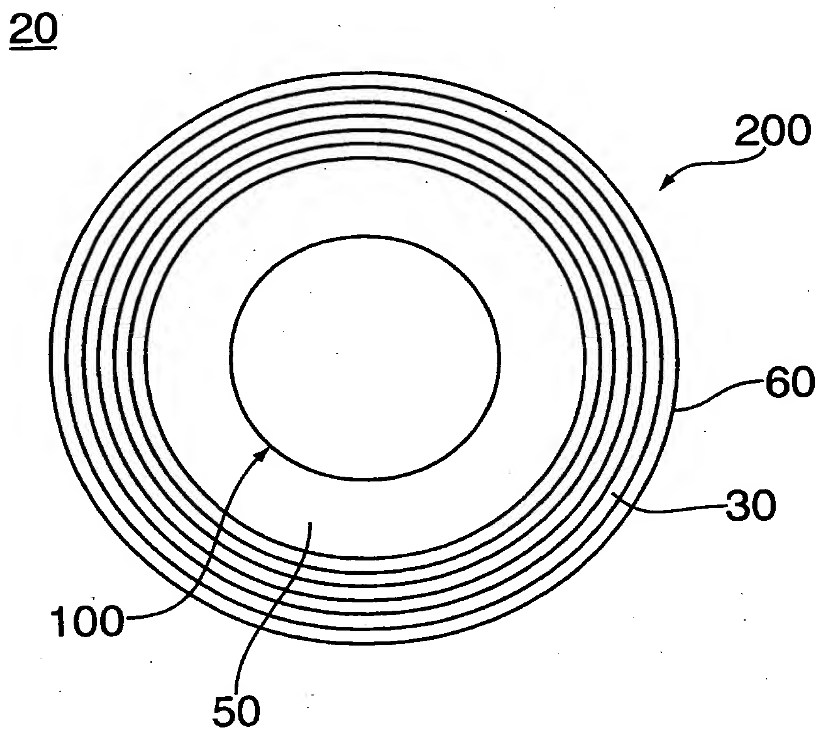

FIG. 1
PRIOR ART

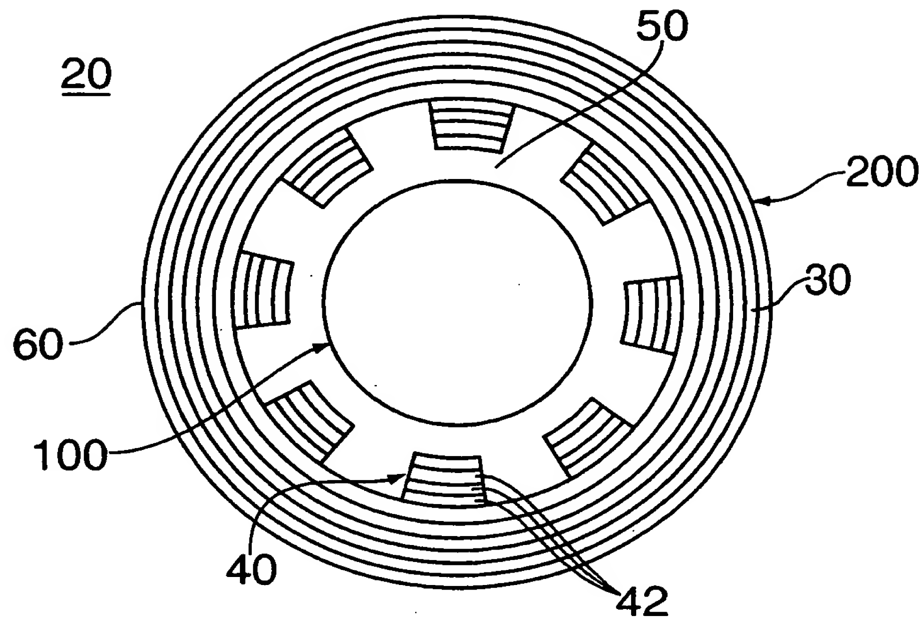

FIG. 2A
PRIOR ART

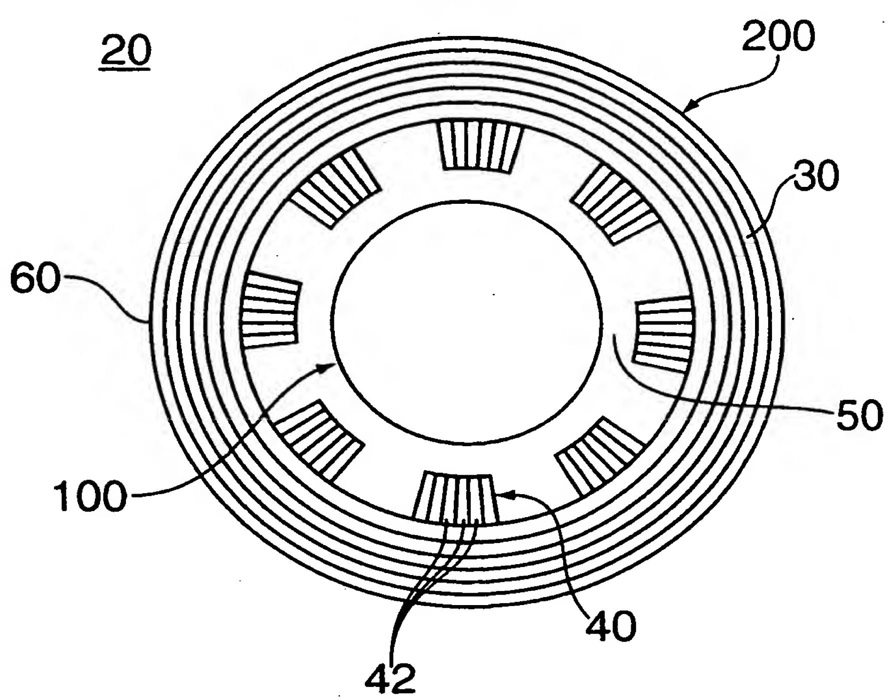

FIG. 2B
PRIOR ART

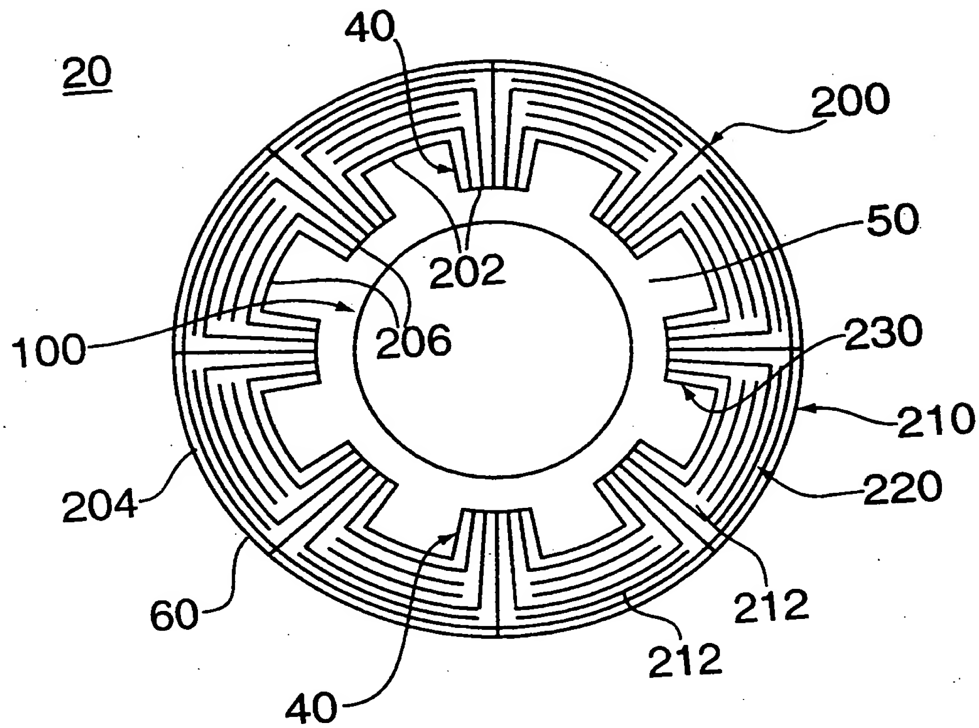

FIG. 3

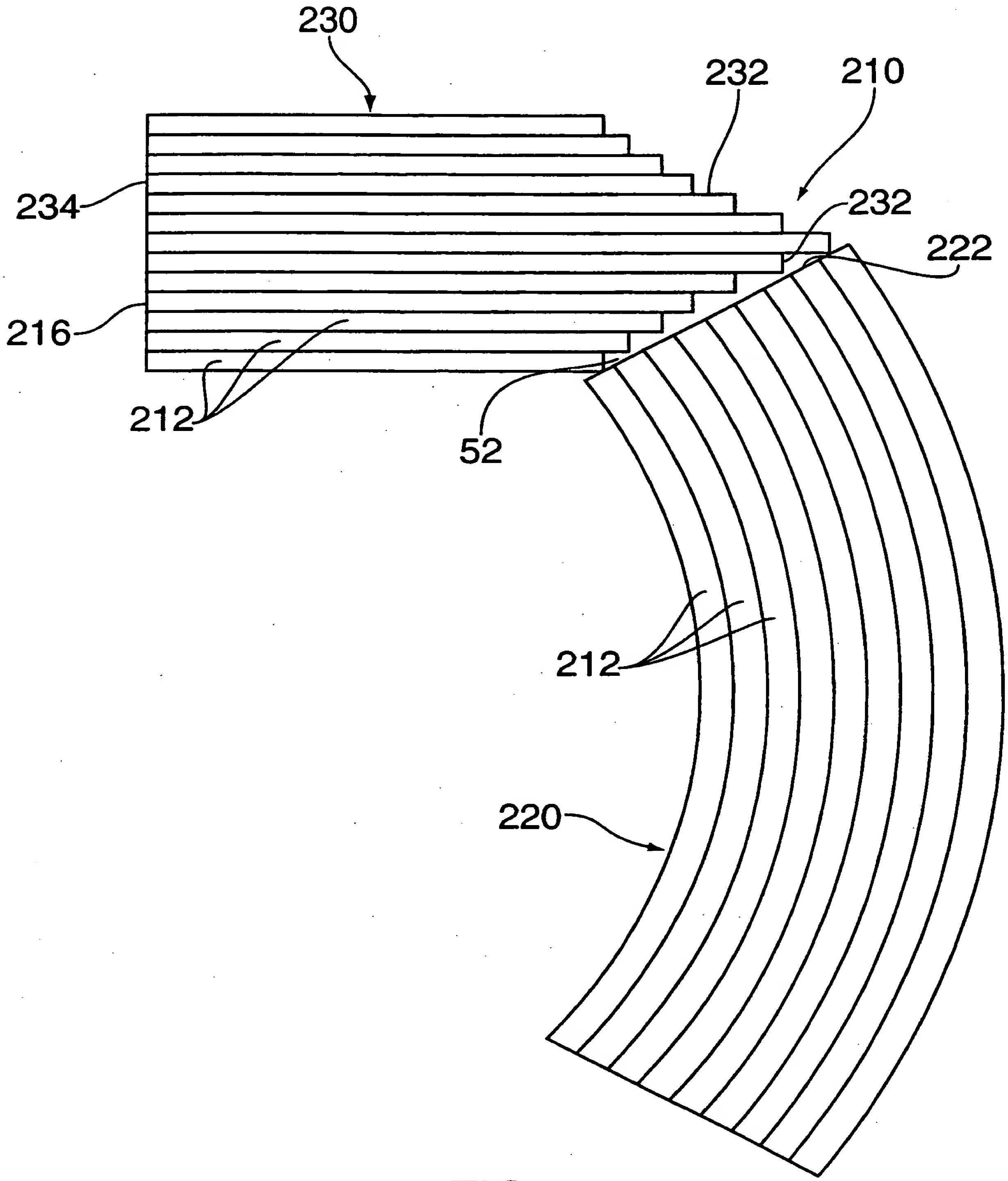

FIG. 4

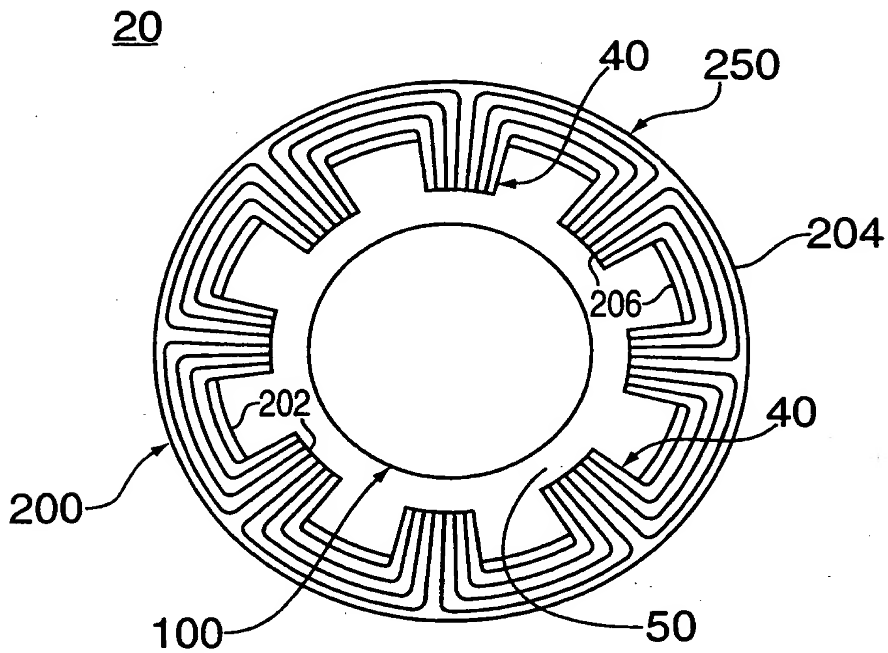

FIG. 5

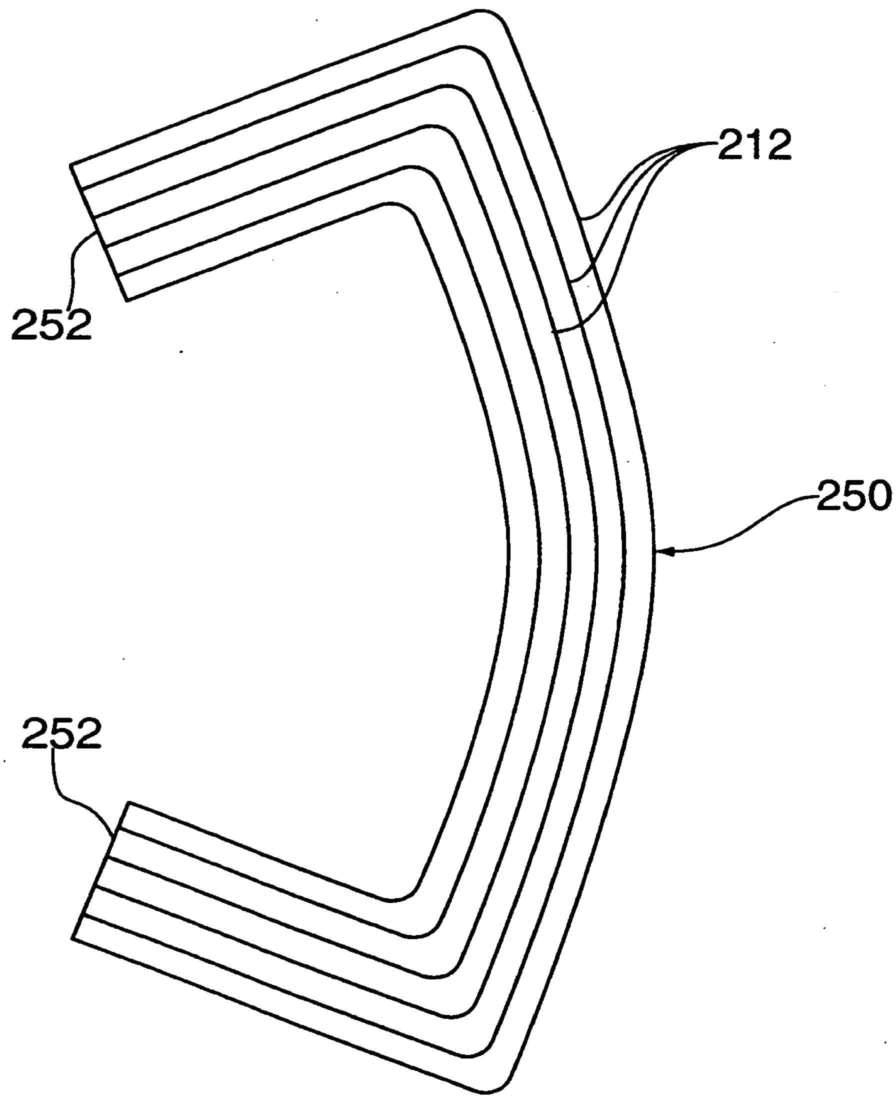

FIG. 6

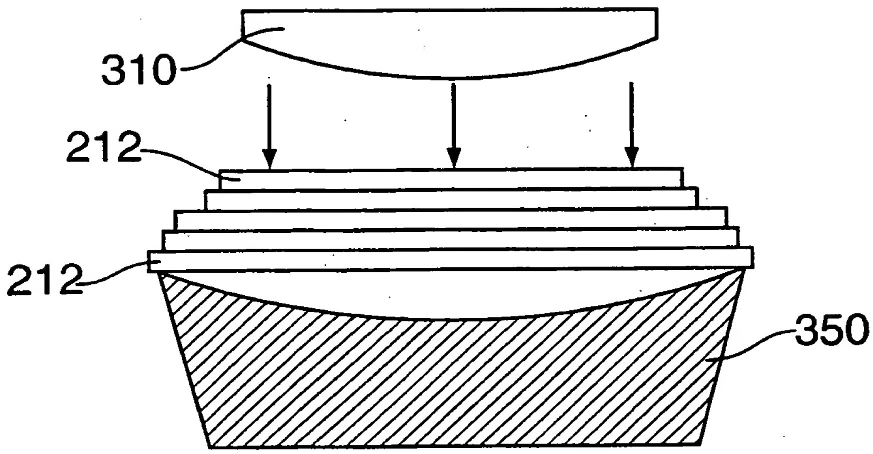

FIG. 7A

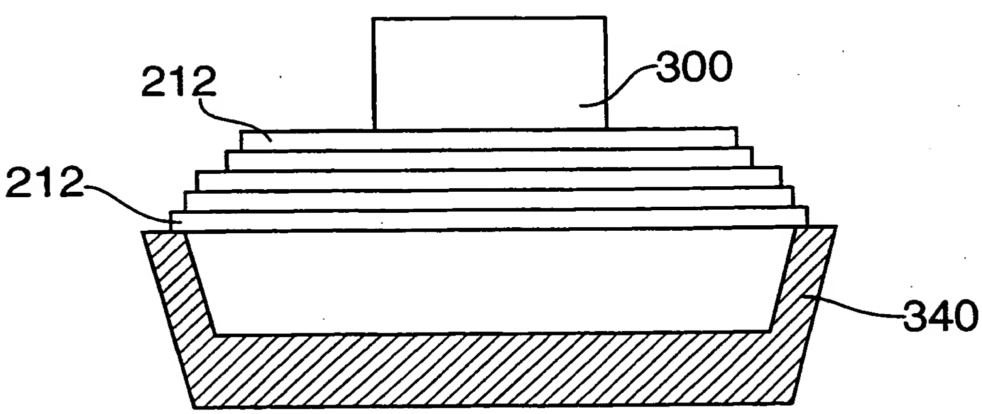

FIG. 7B

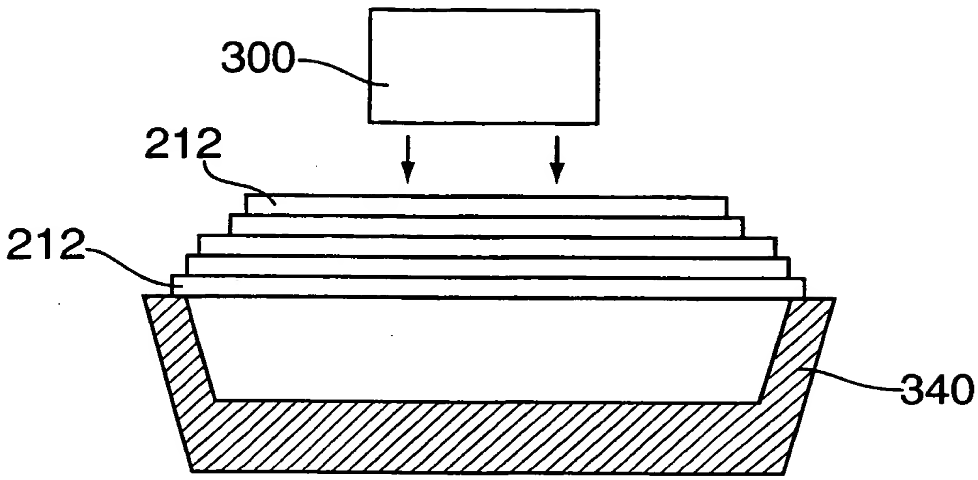

FIG. 7C

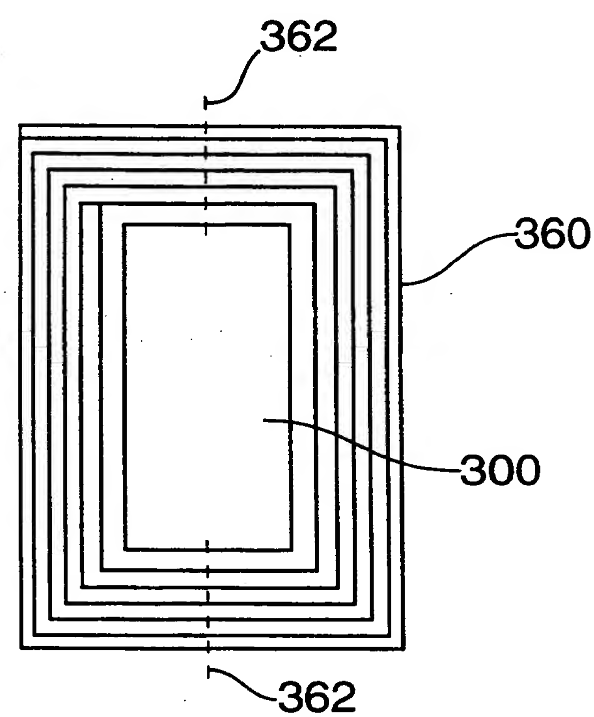

FIG. 7D

INTERNATIONAL SEARCH REPORT

Inte   onal Application No
PCT/US 99/13732

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H02K1/14 H02K15/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 28 05 438 A (EISEN- U. METALLINDUSTRIE E. BLUM KG.) 16 August 1979 (1979-08-16) page 6, line 10 -page 7, line 20 page 11, line 1 -page 15, line 24; figure 1 ---	1,2,8, 19-22,25
Y	US 5 731 649 A (CAAMANO) 24 March 1998 (1998-03-24)	19,20
X	abstract	21,37
A	column 1, line 38 -column 2, line 42 column 16, line 10 -column 17, line 18; figures 10,11 ---	1,2,8
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 October 1999	02/11/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Beitner, M

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/13732

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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